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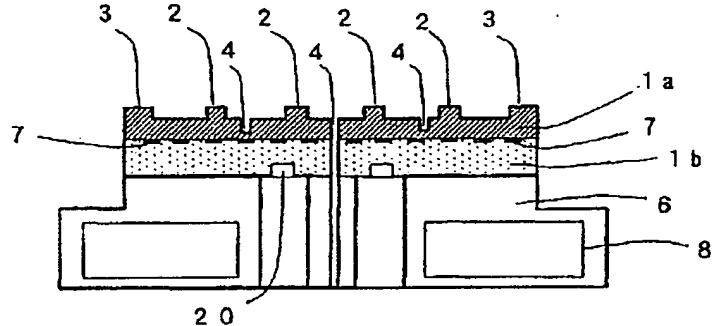
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(54)Title: ELECTROSTATIC CHUCK AND TREATING DEVICE

(54)発明の名称: 静電チャックおよび処理装置



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(57)Abstract: An electrostatic chuck for insulating substrate attraction, comprising a dielectric substrate (1a) acting on one surface thereof as an attraction surface of an insulating substrate and provided on the other surface with a plurality of electrodes (7) in order to electrostatic-attracting an insulating substrate such as a glass substrate, an insulating support base (1b) for fixing the dielectric substrate, a plurality of conducting terminals provided on the insulating support base, and a means for electrically connecting the electrodes with the conducting terminals, wherein a resistivity at room temperature of the dielectric substrate is up to $10^{13} \Omega \text{cm}$, a thickness of the dielectric substrate up to 2 mm, a width of an electrode up to 4 mm, and an interval between electrodes up to 2 mm. A heating/cooling plate (6), a gas supply piping for supplying gas to a gap between the insulating substrate and the attraction surface, and a temperature control system for controlling the temperature of the insulating substrate are added to the above electrostatic chuck for insulating substrate attraction to constitute an insulating substrate treating device.

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(57) 要約:

ガラス基板などの絶縁性基板を静電吸着するために、一方の面を絶縁性基板の吸着面とし、他方の面に複数の電極 7 を設けた誘電体基板 1 a と、誘電体基板を固定する絶縁性支持基盤 1 b と、絶縁性支持基盤に設けられた複数の導電性端子と、前記電極と前記導電性端子とを電気的に接続する手段とからなる絶縁性基板吸着用静電チャックにおいて、誘電体基板の抵抗率を室温で $10^{13} \Omega \text{ cm}$ 以下、誘電体基板の厚さを 2 mm 以下、電極の巾を 4 mm 以下、電極間の間隔を 2 mm 以下とした。また、前記絶縁性基板吸着用静電チャックに加熱冷却用の 'プレート 6'、絶縁性基板と吸着面との間隙にガスを供給するガス供給管、絶縁性基板の温度を調節する温度制御システムを付加し、絶縁性基板処理装置を構成した。

明細書

静電チャックおよび処理装置

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技術分野

本発明はPDP（プラズマディスプレー）製造装置、DVD（デジタルビデオディスク）マスタライタ製造装置、ハードディスク製造装置に使用される基板処理装置及びEB（エレクトロンビーム）露光装置におけるレチクル固定装置、更にSOS（シリコンオンサファイア）やSOI（シリコンオンインシュレータ）ウェハ上に形成される素子を製造するCVD、エッチング装置やスパッタリング装置に使用される絶縁性基板処理装置に関するものである。

背景技術

15 DVDやPDP製造装置等においては、被処理体がガラス基板であり電気絶縁性を示す。そのため従来はこれらの基板を真空中で静電吸着することができずその製造装置においてステージ上に平置きされたり、機械的な機構により固定され処理されていた。

EB露光機のレチクルは石英製であり同様に電気絶縁性を示す。そのため真空下でレチクルを固定するために従来は機械的な機構により固定されていた。

シリコンウェハの次世代代替品として注目されているSOS基板やSOI基板はステージ載置面が電気絶縁性を示す。そのため従来はこれらのウェハ上に素子を形成する製造装置においてシリコンウェハの場合のような静電チャックを用いた固定方法を採用することができなかった。シリコンウェハを静電吸着する手段および原理は特開平5-63062に開示されているがその原理によると絶縁性基板は静電吸着することができない。

また静電プロッタのように紙を静電気的に吸引する装置があった。

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DVD、PDP、ハードディスク用の基板上やSOS、SOI上に形成される素子等のプロセスの高度化、高集積化にともないこれらのプロセスの温度管理が非常に重要になってきた。従来から用いられているシリコンウェハ上に形成する素子のプロセスには静電チャックを用いたプロセスの温度管理が実施されている。

しかし従来の静電チャックは導体、半導体しか吸着できなかつたため被処理体が電気絶縁性の場合、静電吸着固定することができずプロセスの高精度な温度管理は不可能であった。

そこで、絶縁性基板をも静電吸着できる静電チャック及び静電チャックを用いた絶縁性基板処理装置が要望されている。

EB露光機のレチクル固定についても機械式固定より簡単な構造でパーティクル発塵の問題も少ない静電チャック方式が要望されている。

本発明は、上記課題を解決するためになされたもので、本発明の目的は、ガラス基板などの絶縁性基板を静電吸着することができる静電チャック、その静電チャックを用いた絶縁性基板加熱冷却装置および絶縁性基板の温度制御方法を提供することである。

発明の開示

本発明の静電チャックは、静電チャックを構成する誘電体の一方の側にある複数の電極間の距離を小さく誘電体の厚さを薄くした。そして電極間に電位差を与える誘電体の吸着面上に不均一電界を形成させた。その不均一電界に存在する被処理体である絶縁体は一部分極し、電界強度の強い方向へ引き寄せられるGradient力(グラジエント力)を発生する。Gradient力は $F \propto \alpha \cdot \text{grad}E^2$ (FはGradient力、 α は誘導分極電荷、Eは電界)となり本発明はこの効果を利用したものである。

上記の効果を發揮するために請求の範囲第1項～第10項は、誘電体の形状、物性、電極の形状を規定し絶縁性基板吸着用静電チャックを開示した。

請求の範囲第11項～第13項は前記静電チャックを用いた減圧下での絶縁性基板の処理方法を開示した。

請求の範囲第14項～第15項は前記静電チャックにプロセスによって発生する熱や、絶縁性基板に供給する熱を媒体によって供給または放散させるための流路を設けたプレートと、絶縁性基板と誘電体吸着面間の隙間の熱伝達を調整するため封止するガスを供給するためのガス供給配管、及び絶縁性基板の温度によって前記の封止するガス圧力を調整し予め設定した温度に調節が可能になる絶縁性基板加熱冷却装置及び温度制御システムを開示した。

10 図面の簡単な説明

図1は、静電チャックの一例を示す平面図である。

図2は、A-Aに沿った図1の断面図である。

図3は、静電チャックにより絶縁性基板を吸着した別実施例の断面図である。

図4は、誘電体に設けられた電極のパターン例である。

15 図5は、誘電体に設けられた電極のパターン例である。

図6は、誘電体に設けられた電極のパターン例である。

図7は、加熱冷却ガス圧力と絶縁性基板の温度との関係を示すグラフである。

図8は、静電チャックの印可電圧と絶縁性基板の温度との関係を示すグラフである。

20 図9は、静電チャックの固体接触部の面積比率と絶縁性基板の温度との関係を示すグラフである。

発明を実施するための最良の形態

本発明の好適な実施例を図を用いて説明する。図1は本発明に係る静電チャックの一例を示す平面図であり、図2はその断面図である。

図3は絶縁性支持基盤1bを誘電体基板1aと同質の材料とし積層構造にすることによって一体化した実施例であり、静電チャック1に絶縁性基板10を吸着した

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状態を示す断面図である。同図において電圧印可用導線 1 2 を通じて電極 7 に電圧を印可することで、絶縁性基板 1 0 と静電チャック 1 との間に吸着力を発生させ、ドット 2 及び外周シールリング 3 (以下、まとめて固体接触部と記す) において絶縁性基板 1 0 を吸着する。また静電チャック 1 は接合部 1 1 を通じて金属製プレート 6 と接合されており、金属製プレート 6 内部に設けられた媒体流路 8 に媒体を流すことで静電チャック 1 の加熱冷却を行う。

図4～図6は前記実施例に代表される誘電体の一方の面に形成される電極7のパターンの一例である。電極7を複数の対にすることにより、SOSやSOIウェハのプラズマプロセスにおいて使用される高周波電流を各々の電極に分散させ導電性端子等1ヶあたりの負荷を減じることができる。

ガス供給配管 13 を通じてガス供給口 5 からガスが供給され、ガス封入部 9 に封入される。このときにガスを蒸早く均一に封入するために静電チャック 1 の表面に溝 4 が設けられている。このガス封入部 9 及び固体接触部を通じて絶縁性基板 10 と静電チャック 1 の間の熱伝達が行われる。

15 ガス供給配管近傍にガス圧力計 16 が設置され圧力によって信号電圧を 0 ~ 10 V の範囲で出力する。

ガス配管には圧力コントロールバルブ17が設置され、ガス圧力計16の信号電圧と設定値を比較しバルブの開閉を行うことでガスの圧力を設定値に調節することができる。

以下表 1 に誘電体の特性を表したときの静電吸着力を測定した結果を示す。

尚、静電吸着力の測定は面積が 5 cm^2 の被吸着体を用意し、静電チャックに DC 電圧を 3 ~ 10 KV 印可した。そのときに被吸着体を横方向から力を加え被吸着体が静電吸着力に抗して動き出すときの力をバネばかりで計測した。バネばかりの最大荷重が 300 g であったためそれ以上の力は計測できなかったが、誘電体と被吸着体の静止摩擦係数を 0.2 としても計測値の約 5 倍の抗力に相当する静電吸着力が現していることになる。よって計測値 $300 \text{ g} / 5 \text{ cm}^2$ で約 $300 \text{ g} / \text{cm}^2$ の引張り強度に相当する。この値は約 30 KPa に相当し真空チャンバ内で被吸着体を吸着するには十分な力である。誘電体の形状は一定にするため表 1 の試験は全て電極巾 1 mm、電極間隔 1 mm、誘電体厚さ 0.5 mm とした。

1 A ~ 1 D、2 は誘電体基板の抵抗率を変えたときの静電吸着力の関係である。抵抗率はあまり静電力に影響を受けないようであるが $10^{13} \Omega \text{ cm}$ 以下であるほうが大きい静電吸着力が発現するようであり使用しやすいといえる。

1 F、1 G は絶縁性基板の表面粗さを変えたときの静電吸着力である。1 B と比較すると表面粗さは $R_a 0.25 \mu\text{m}$ 以下が望ましいことがわかった。本実施例で使用した絶縁性基板の表面粗さは 1 P の多結晶アルミナ基板を除き $R_a 0.1 \mu\text{m}$ 以下であった。

1 B、2 ~ 6 は誘電体の材料を変えたときの静電吸着力の関係である。誘電体の物性として比誘電率よりも抵抗率と関連が大きいようであった。材料はアルミニナに酸化クロム、酸化チタンを添加したセラミックス焼結体およびそれに焼結助材を加えた材料が最も安定し大きな吸着力が得られた。

1 B、1 H ~ 1 N は被吸着体の種類を変えて静電吸着力を測定した。その結果、他の絶縁性材料であっても静電吸着できることが確認され、比誘電率の大きな被吸着体ほど大きな力が発現した。

25 1 O、1 P は被吸着体を多結晶アルミナ基板にし、表面粗さを変えたときの静電吸着力を測定した。その結果、被吸着体の表面粗さが $R_a 0.4 \mu\text{m}$ 程度であるならば吸着力が十分得られることがわかった。被吸着体の比誘電率が大きくな

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るほど被吸着体の表面粗さが粗くできることがわかった。

誘電体の材料をかえたときの静電吸着力を2~7に示した。アルミナに酸化クロム、酸化チタンを添加したセラミックス焼結体以外でも静電吸着することが示された。被吸着体がPDP用ガラスの場合は、その視認性の点からもガラスに傷が入りにくいゴム系の材料が有効である。本実施例ではシリコンゴムを用いたが天然ゴム、クロロブレンゴム、ブチルゴム、ニトリルゴム、フッ素ゴム更にポリウレタン、PTFE等の樹脂であっても良い。この場合体積抵抗率が $10^{13}\Omega\text{cm}$ 以下が望ましい。

表2は、アルミナに酸化クロム、酸化チタンを添加したセラミックス焼結体からなる材料を用い、本発明にかかる静電チャックの電極パターンを変えたときのガラス基板の静電吸着力と印可電圧(10KV印可)との関係である。

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【表 2】

NO	本発明の範囲	誘電体厚さ (μm)	電極 巾 (mm)	電極間 距 (mm)	静電 吸着力 (g/5cm ²) 10KV
7	×	300	0.3	0.3	放電
8	○	300	0.5	0.5	放電
9	○	300	0.7	0.7	>300
10	○	300	1.0	1.0	>300
11	○	300	2.0	2.0	180
12	×	300	3.0	3.0	30
13	○	300	0.5	1.0	>300
14	○	300	0.5	1.5	200
15	○	300	2.0	1.0	250
16	○	300	4.0	1.0	120
17	×	300	6.0	1.0	30
18	×	400	0.3	0.3	放電
19	○	400	0.5	0.5	>300
20	○	400	0.7	0.7	>300
21	○	400	1.0	1.0	>300
22	○	400	2.0	2.0	120
23	×	400	3.0	3.0	30
24	○	400	0.5	1.0	>300
25	○	400	0.5	1.5	200
26	○	400	2.0	1.0	200
27	○	400	4.0	1.0	100
28	×	400	6.0	1.0	20
29	×	500	0.3	0.3	放電
30	○	500	0.5	0.5	放電
31	○	500	0.7	0.7	>300
32	○	500	1.0	1.0	280
33	○	500	2.0	2.0	100
34	×	500	3.0	3.0	20
35	○	500	0.5	1.0	>300
36	○	500	0.5	1.5	200
37	○	500	2.0	1.0	165
38	○	500	4.0	1.0	45
39	×	500	6.0	1.0	25
40	×	700	0.3	0.3	放電
41	○	700	0.5	0.5	240
42	○	700	0.7	0.7	240
43	○	700	1.0	1.0	220
44	○	700	2.0	2.0	90
45	×	700	3.0	3.0	20
46	○	700	0.5	1.0	260
47	○	700	0.5	1.5	150
48	○	700	2.0	1.0	140
49	○	700	4.0	1.0	50
50	×	700	6.0	1.0	20

NO	本免明 の範囲	誘電体 厚さ (μ m)	電極 巾 (mm)	電極間 距 (mm)	静電 吸着力 (g/5cm ²) 10KV
51	X	1000	0.3	0.3	放電
52	○	1000	0.5	0.5	200
53	○	1000	0.7	0.7	200
54	○	1000	1.0	1.0	180
55	○	1000	2.0	2.0	70
56	X	1000	3.0	3.0	20
57	○	1000	0.5	1.0	220
58	○	1000	0.5	1.5	120
59	○	1000	2.0	1.0	120
60	○	1000	4.0	1.0	30
61	X	1000	6.0	1.0	10
62	X	2000	0.3	0.3	放電
63	○	2000	0.5	0.5	170
64	○	2000	0.7	0.7	130
65	○	2000	1.0	1.0	100
66	○	2000	2.0	2.0	10
67	X	2000	3.0	3.0	10
68	○	2000	0.5	1.0	120
69	○	2000	0.5	1.5	30
70	○	2000	2.0	1.0	70
71	○	2000	4.0	1.0	30
72	X	2000	6.0	1.0	10

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同一の電極巾、電極間距離のパターンでは誘電体の厚さは0.3 mmがもっとも静電吸着力が大きく、薄くすれば静電吸着力が大きくなる傾向にある。

電極巾、間隔とも0.5mm以上であれば静電吸着力が可能であることがわかつたが、電極間隔が0.5mmより狭い場合は電極間の絶縁が十分得られなくなり結果として静電吸着できない場合もあった。

同一誘電体厚さで比較すると電極巾が狭いほど大きな静電吸着力が得られた。電極間距離が 2 mm より大きい場合はほとんど静電吸着力が得られなかつた。今回の試験では印可電圧を 10 KV まで印可したが更に大きな電圧を印可すれば電極間距離 2 mm でも静電吸着力が発現することが期待される。

10 同一誘電体厚さ、同一電極巾で比較すると電極間隔が誘電体の厚さより大きくなると静電吸着力が小さくなる傾向にあった。

以上をまとめると、誘電体の厚さは薄く、電極の巾は狭く、電極間は電極の巾と同程度である場合に大きな静電吸着力が得られることがわかった。

被吸着体としてガラス基板を静電吸着する場合は誘電体厚さは0.3mm～2.15mm、電極間隔が0.5～1mm以下、電極巾は0.5mm～4mm、誘電体の抵抗率 $10^{13}\Omega\text{cm}$ 以下で実用化できるが、更により好ましくは誘電体厚さは0.3mm～1.0mm、電極間隔が0.5～1mm以下、電極巾は0.5mm～1mm、誘電体の抵抗率 $10^{13}\Omega\text{cm}$ 以下が望ましい。

次に基板加熱冷却装置の実施例について記載する。

20 図 7～9 は各種熱吸着試験データおよび絶縁性基板冷却試験特性の実験データを示すグラフであり、各グラフの説明を以下に示す。絶縁性基板 10 は、ガラス基板（低アルカリガラス）を用いた。

図7は真空チャンバ内に設置した基板加熱冷却装置に絶縁性ガラス基板を設置し、絶縁性基板の温度と絶縁性基板と誘電体吸着面の間隙に供給される加熱冷却用ガスの圧力との関係である。絶縁性基板10の上面から $2\text{W}/\text{cm}^2$ の熱流を与えたときの熱特性を、横軸に上記ガスの圧力、縦軸に絶縁性基板10の表面温度として表した。ガス封入部9のガス圧力を変化させることで絶縁性基板10の温

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度を制御できる様子が確認できる。本実験では主にHeガスをもちいたがArやN₂を用いても同様の加熱冷却効果が発揮される。

より高い圧力を供給し加熱冷却の効率を大きくするにはガスの圧力を分子流領域とするため、誘電体吸着面19のドット2の高さを低く設定する必要がある。

5 例え上記ガスにおいて0~13329Pa(0~100Torr)まで分子流領域とするにはドット2の高さを5μm以下にすればよい。このとき上記ガスを素早く均一に封入するためにドット2と同時に溝4の形成が重要となる。

10 静電チャック表面に凸状のドットのみが設けられた場合は、ドットの高さによっては隙間空間内の圧力が均一になるまでに時間がかかる。そこでガス供給口から溝を掘ることによって隙間空間内の圧力が均一になるまでの時間を低減させている。溝の形状、パターンはガス供給口から放射状であり巾1mm以上、深さは50μm以上で効果を奏する。好ましくは巾1.5mm以上、深さ250μm以上でありこの場合隙間の圧力分布が均一になるまで5秒以下となる。溝のパターンは放射状と同心円状を組み合わせることにより更に効果が増加する。

15 印可電圧を変化させると絶縁性基板10の温度を変化させられる。このとき静電チャックの表面粗さを変化させることによって図8のように絶縁性基板温度を調節できる。

更に、接触面積比率を変えることで絶縁性基板10の温度が変化することを確認した実験結果を図9に示した。接触面積比率をかえるにはドットの数及びドットの直径をかえる必要がある。本実施例に用いたドットの直径は5mmで、シリリング巾は4mmであった。ドットの数は接触面積比率から換算した。ドットは静電チャック表面上に概略等分散に配置した。

20 本実施例により、ガス封入部9に6664Pa(50Torr)という高いガス圧力を封入することで絶縁性基板10に対する大きな加熱冷却効果を得られることがわかったが、そのためには強い吸着力を発生する静電チャックが必要である。例えば、接触面積比率を20%にして1333Pa(10Torr)のガス圧力を封入するには、理論上、13g/cm²の吸着力、が最低限必要である。よって吸着力が

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非常に大きい静電チャックが必要となる。ここでは静電チャックの絶縁層の材料としてアルミナを主成分とし、酸化クロム (Cr₂O₃)、酸化チタン (TiO₂) および焼結助材を適量添加したセラミック焼結体を用いた。この材料の吸着力は 1 A ~ 1 C と同じく 10 KV 印可で約 300 g / 5 cm² であり垂直方向の引張り強度が 300 g / cm² と推定される。接触面積比率が 20 % であっても 60 g / cm² 以上が確保でき十分に絶縁性基板を吸着できる。

本実施例では、絶縁性基板10として、低アルカリガラス基板を用いたが、本発明の静電チャックは、電気絶縁性基板およびフィルム一般に適用できる。

また絶縁性基板加熱冷却装置の絶縁性支持基盤内にヒーターを設け、被吸着体を測温する手段として光温度計、熱電対、その他非接触温度計を設けその計測器から出力される信号と予め設定した値とを比較することにより被吸着体の温度制御が容易になる。また絶縁性基板を直接測温できない場合は予め蓄積されたガス圧力、印可電圧、固体接触面積比率、入射熱エネルギー、媒体流量、媒体温度等の関連を記載されたデータベースに基づき絶縁性基板の温度を一定に保つ調整が可能になる。

本実施例で開示した絶縁性基板加熱冷却装置を反応チャンバ内に設置することにより、SOSやSOIウェハのプラズマCVD、プラズマエッティングやスペッタリング等の半導体製造プロセスでの温度管理が非常に容易になる。

20 産業上の利用可能性

以上に説明した如く本発明によれば、被処理体が絶縁体である場合も静電チャックを用いて吸着することができるため、静電チャックを組み込んだ加熱冷却装置を用いれば絶縁性基板の加熱、冷却が容易になり絶縁性基板を所定の温度に制御することが可能となる。

請求の範囲

1. 一方の面が絶縁体基板を吸着する吸着面とし、もう一方の面に複数の電極が設けられた誘電体基板と、該誘電体基板を固定する絶縁性支持基盤と、該絶縁性支持基盤に設けられた複数の導電性端子と、前記誘電体基板に設けられた電極と、前記導電性端子を電気的に接続する手段と、からなる絶縁性基板吸着用静電チャック。
2. 前記誘電体基板の抵抗率は室温で $10^{13} \Omega \text{ cm}$ 以下であることを特徴とする請求の範囲第1項に記載の静電チャック。
3. 前記誘電体基板の厚さは 2 mm 以下であることを特徴とする請求の範囲第1項または第2項に記載の静電チャック。
4. 前記誘電体基板の材料はアルミナを主原料とし、クロミア、チタニアを添加して焼成し得られたセラミックスであることを特徴とする請求の範囲第1項～第3項のいずれか1項に記載の静電チャック。
5. 前記誘電体基板の吸着面には溝と、凸状のドットと、外周シールリングを有することを特徴とする請求の範囲第1項～第4項のいずれか1項に記載の静電チャック。
6. 前記誘電体基板のもう一方の面に設けられた複数の電極は、1対をなし、各々の電極の巾は 4 mm 以下であり、電極間の間隔 2 mm 以下であり、各々の電極が櫛歯状に入り組んでいることを特徴とする請求の範囲第1項～第5項のいずれか1項に記載の静電チャック。
7. 前記誘電体基板のもう一方の面に設けられた複数の電極は、複数の対をなし、各々の電極の巾は 4 mm 以下であり、電極間の間隔は 2 mm 以下であり、各々の電極が櫛歯状に入り組んでいることを特徴とする請求の範囲第1項～第5項のいずれか1項に記載の静電チャック。
8. 前記絶縁性支持基盤の材料は、前記誘電体基板の材料の抵抗率より大きい

ことを特徴とする請求の範囲第1項～第7項のいずれか1項に記載の静電チャック。

9. 前記導電性端子は、前記絶縁性支持基盤にロウ付け、はんだ付け、導電性接着剤のいずれかによる接着により設けられていることを特徴とする請求の範囲第1項～第8項のいずれか1項に記載の静電チャック。

10. 前記電気的接続手段は、導電性ワイヤー、導電性棒、導電性樹脂充填、ハンダ充填のいずれかによることを特徴とする請求の範囲第1項～第9項のいずれか1項に記載の静電チャック。

11. 一方の面が絶縁体基板を吸着する吸着面とし、もう一方の面に複数の電極が設けられた誘電体基板と、前記誘電体基板を固定する前記絶縁性支持基盤と、該絶縁性支持基盤に設けられた複数の導電性端子と、前記誘電体基板に設けられた複数の電極と、前記導電性端子とを各別々に電気的に接続する手段と、高圧電源と、高圧電源と前記複数の導電性端子とを電気的に接続する手段と、を有し、前記吸着面に載置された絶縁性基板を静電吸着することを特徴とする絶縁性基板静電吸着処理方法。

12. 真空減圧下で処理することを特徴とする請求の範囲第11項記載の絶縁性基板静電吸着処理方法。

13. 絶縁体である被処理基板を静電吸着し、被処理基板と誘電体吸着面との間に形成された隙間空間内に、被処理基板の加熱・冷却を行うガスを封入し、該ガスの圧力領域が、分子流領域であることを特徴とする請求の範囲第11項または第12項に記載の絶縁性基板静電吸着処理方法。

14. 請求の範囲第1項～第10項のいずれかに記載の静電チャックと、該静電チャックを支持するための媒体流路が内蔵されているプレートと、該静電チャックと該プレートとを接着する手段と、からなる絶縁性基板加熱冷却処理装置。

15. 請求の範囲第1項～第10項のいずれかに記載の静電チャックと、該静電チャックを支持するための媒体流路が内蔵されているプレートと、静電チャックと該プレートとを接着する手段と、誘電体および絶縁性支持基盤およびプレー

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トを貫くガス供給配管と、ガスの圧力を計測する圧力計と、ガスの圧力計が出力する電気信号を入力し、予め設定した圧力に制御するようにバルブを開閉する機能を有する圧力コントロールバルブと、絶縁性基板の温度を計測する計測器または、絶縁性基板の温度とガス圧力の関係を記録したデータベースと、を有し、真
5 空減圧下で、絶縁性基板の温度を設定した温度に調節することができる絶縁性基板加熱冷却処理装置。

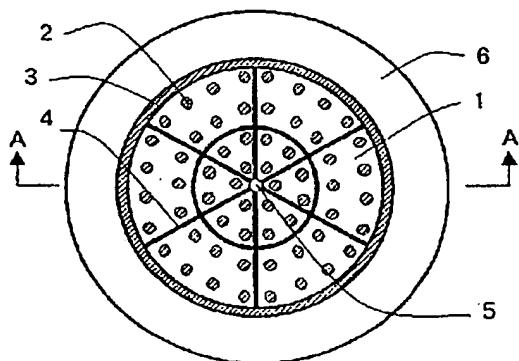
16. 絶縁性基板はガラスであることを特徴とする請求の範囲第1項～第10項いずれかに記載の静電チャック、または、請求の範囲第11項～第13項いずれかに記載の絶縁性基板処理方法、または、請求の範囲第14項～第15項いずれかに記載の処理装置。

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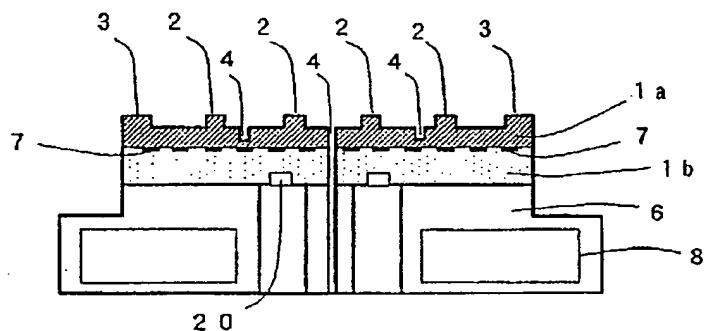
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〔図1〕



〔图2〕

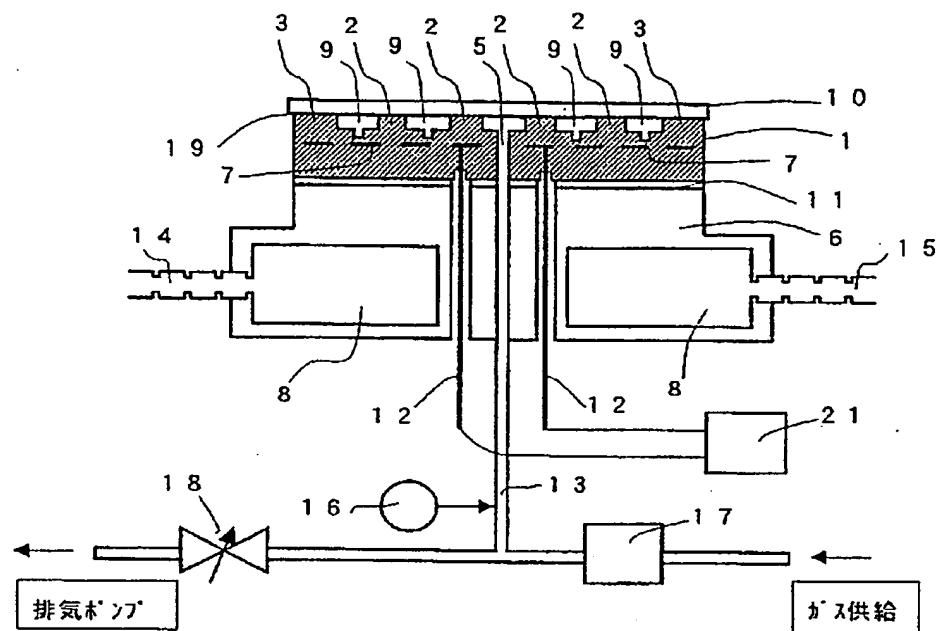


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[図3]

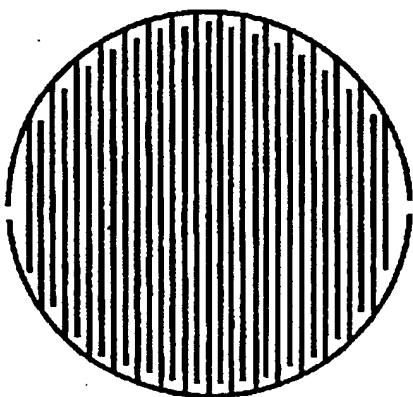


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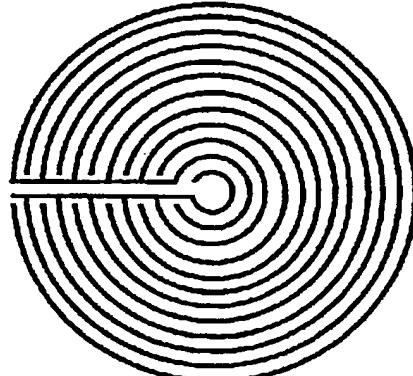
PCT/JP00/03355

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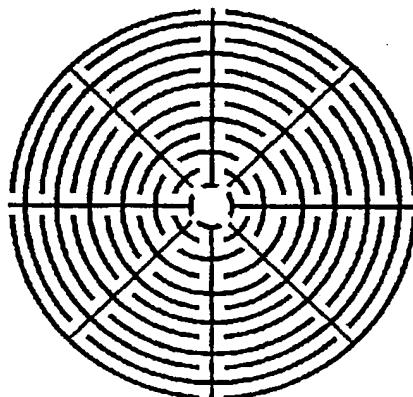
[4]



[図 5]



【图 6】

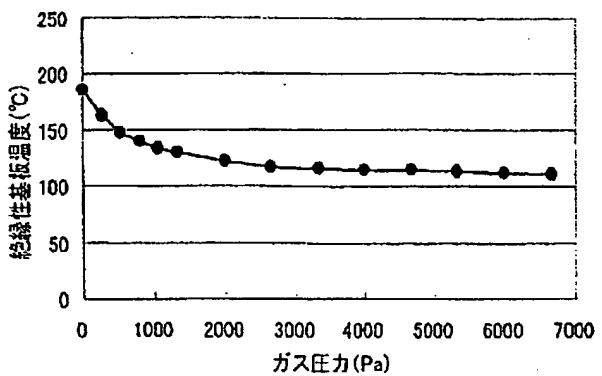


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【図7】

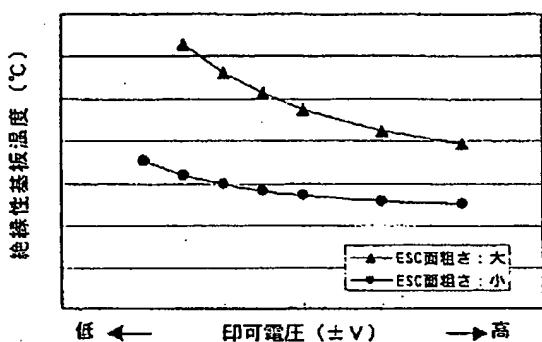


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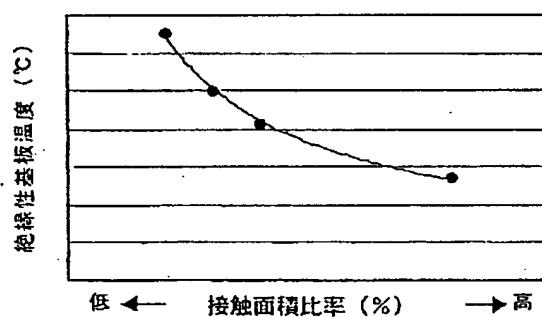
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〔图8〕



[图 9]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/03355

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl' H01L21/68, B23Q3/15, H02N3/15

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl' H01L21/68, B23Q3/15, H02N3/15

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-2000
Kokai Jitsuyo Shinan Koho 1971-2000 Jitsuyo Shinan Toroku Koho 1996-2000

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 11-100271, A (Kyocera Corporation), 13 April, 1999 (13.04.99), Claims; Par. Nos. [0001] to [0002], [0031] to [0032], [0043] to [0044]; Fig. 1 (Family: none)	1-16
Y	JP, 10-242256, A (Kyocera Corporation), 11 September, 1998 (11.09.98), Par. Nos. [0001] to [0002], [0014] to [0016], [0024] to [0025]; Figs. 1, 2 (Family: none)	1-16
Y	JP, 11-8291, A (Hitachi, Ltd.), 12 January, 1999 (12.01.99), Par. Nos. [0014] to [0019] (Family: none)	3-10, 14-16
Y	JP, 5-211228, A (Toto Ltd.), 20 August, 1993 (20.08.93), Claims & TW, 236709, A	4-10,14-16
Y	EP, 790641, A (Novellus Systems, Inc.), 20 August, 1999 (20.08.99), page 7, lines 9-23; page 9, lines 14 to page 10, line 18;	5-10, 14-16

 Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier document but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 21 August, 2000 (21.08.00)	Date of mailing of the international search report 29 August, 2000 (29.08.00)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/03355

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Figs. 10, 11, 15 to 19 & US, 5810933, A & JP, 9-232415, A & TW, 300312, A & KR, 97063549, A & SG, 69168, A	
Y	JP, 10-223742, A (Kyocera Corporation), 21 August, 1998 (21.08.98), Claims; Par. Nos. [0001], [0020] to [0029]; Fig. 2 (Family: none)	6-10, 14-16
Y	EP, 803904, A (APPLIED MATERIALS, INC.), 29 October, 1997 (29.10.97), page 3, lines 29-49; page 6, lines 35-39; page 6, lines 55-56; page 7, lines 3-21; Figs. 1, 3 to 5, 7 & US, 5761023, A & JP, 10-41378, A	13,16
Y	JP, 9-17770, A (Sony Corporation), 17 January, 1997 (17.01.97), Par. Nos. [0028] to [0029]; Fig. 1 (Family: none)	14,16

国際調査報告		国際出願番号 PCT/JP00/03355										
<p>A. 発明の属する分野の分類 (国際特許分類 (IPC)) Int.C1' H01L21/68, B23Q3/15, H02N3/15</p>												
<p>B. 調査を行った分野 調査を行った最小限資料 (国際特許分類 (IPC)) Int.C1' H01L21/68, B23Q3/15, H02N3/15</p>												
<p>最小限資料以外の資料で調査を行った分野に含まれるもの 日本国実用新案公報 1926-1996年 日本国公開実用新案公報 1971-2000年 日本国登録実用新案公報 1994-2000年 日本国実用新案登録公報 1996-2000年</p>												
<p>国際調査で使用した電子データベース (データベースの名称、調査に使用した用語)</p>												
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ELECTROSTATIC CHUCK AND PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to a processing apparatus of an insulative substrate for use in a PDP (plasma display) manufacturing apparatus, a master writer manufacturing apparatus for a DVD (digital video (or versatile) disc), a substrate processing apparatus for a hard disc manufacturing apparatus, a reticle fixing apparatus in an EB (electron beam) exposure apparatus, and a CVD, etching or sputtering apparatus for manufacturing elements to be formed on SOS (silicon on sapphire) and SOI (silicon on insulator) wafers.

10 2. DESCRIPTION OF PRIOR ART

In the manufacturing apparatuses for such as a DVD, a PDP or the like, a material to be processed is a glass substrate which shows electrically insulative characteristic. Therefore, in the conventional art, since it is impossible to electrostatically attract these substrates within a vacuum, they are flatly placed on a stage in the manufacturing apparatus thereof or they are fixed with a mechanical mechanism.

A reticle of the EB exposure apparatus is comprised of quartz which also shows electrically insulative characteristic. Therefore, conventionally, the reticle is fixed under a vacuum with a mechanical mechanism.

SOS wafers and SOI wafers, attracting attention as next-generation alternatives to silicon wafers, show electrically insulative characteristic with regards to the surface by which they are mounted on a stage. Therefore, conventionally, it is impossible to apply a fixing method using an electrostatic chuck in the manufacturing apparatus for forming devices on these wafers. A means and a principle of electrostatically attracting a silicon wafer are disclosed, for example, in Japanese Patent Application Laid-Open No. Hei

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5-63062 (1993), however it is impossible to electrostatically attract an insulative substrate in accordance with the principle.

Also, there was known an apparatus for electrostatically attracting a paper, for example, an electrostatic plotter.

As the level and integration is advanced in the process for forming devices or the like on a substrate for use in a DVD, PDP, or a hard disc, or on an SOS or SOI, the temperature control in the process comes to be very important. With regards to the conventional process for forming devices on a silicon wafer, the temperature control is conducted in the process using an electrostatic chuck.

10 However, since the electrostatic chuck of the conventional art can attract only a conductor or semiconductor, a material to be processed cannot be electrostatically attracted in a case of having an electrically insulative characteristic. Therefore, it is impossible to control the temperature in the process with high accuracy.

Therefore, an electrostatic chuck, with which an insulative substrate can be electrostatically attracted, and a processing apparatus using such an electrostatic chuck are desired.

For fixing a reticle in the EB exposure apparatus, there is also desired a method using an electrostatic chuck, the structure of which is simpler than that of a mechanical fixation and which has a less problem of generating dust particles.

20 SUMMARY OF THE INVENTION

According to the present invention, for solving the problems mentioned above, there is provided an electrostatic chuck which can electrostatically attract an insulative substrate, such as a glass substrate, under a vacuum atmosphere and a heating/cooling apparatus and a temperature controller apparatus for an insulative substrate using such an electrostatic chuck.

In the electrostatic chuck according to the present invention, the distance between a plurality of electrodes which are provided on one side of a dielectric constructing the electrostatic chuck is made small, and the thickness of the dielectric is made thin. A potential difference is given between the electrodes so as to form an ununiform electric field upon an attracting surface of the dielectric. An insulative material to be processed being within the ununiform electric field is partially polarized, and generates gradient force that is attracted in the direction being strong in the strength of the electric field. The gradient force is expressed by $F \propto \alpha \cdot \text{grad } E^2$, wherein F is gradient force, α an inductive polarization charge, and E an electric field. The present invention utilizes this effect.

For obtaining the effect mentioned above, according to the present invention described in the present claims 1 to 10, there is provided an electrostatic chuck for attracting an insulative substrate, used under a vacuum atmosphere by specifying the shape and the properties of a dielectric, and the shapes of electrodes.

According to the present invention described in the present claims 14 and 15, there is provided a heating/cooling apparatus, comprising the electrostatic chuck mentioned above, a plate in which a flow passage is formed to supply or diffuse heat generated in the process or heat to be supplied to an insulative substrate by a medium, and a gas supply conduit for supplying a gas which is enclosed within a space defined between the insulative substrate and the attracting surface of a dielectric for adjusting heat transmission therebetween, wherein the pressure of the enclosed gas can be adjusted by the temperature of the insulative substrate and thereby the temperature can be adjusted to a predetermined value.

According to the present invention described in the present claims 11, 13, 18 and 19, there is provided a processing method for an insulative substrate under a vacuum atmosphere, using the electrostatic chuck mentioned above.

According to the present invention described in the present claims 20 to 23, there is provided an apparatus for electrostatically attracting an insulative substrate under a vacuum atmosphere, using the electrostatic chuck mentioned above.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plane view showing an example of an electrostatic chuck;

FIG. 2 is a cross-sectional view along with a cutting line A-A in FIG. 1;

5 FIG. 3 is a cross-sectional view of another embodiment in which an insulative substrate is attracted by an electrostatic chuck;

FIG. 4 is a view showing an example of a pattern of electrodes provided on a dielectric;

10 FIG. 5 is a view showing another example of a pattern of electrodes provided on a dielectric;

FIG. 6 is a view showing another example of a pattern of electrodes provided on a dielectric;

FIG. 7 is a graph showing the relationship between the heating/cooling gas pressure and the temperature of an insulative substrate;

15 FIG. 8 is a graph showing the relationship between the voltage applied to an electrostatic chuck and the temperature of an insulative substrate; and

FIG. 9 is a graph showing the relationship between the area ratio of a solid-body contact portion to an electrostatic chuck and the temperature of an insulative substrate.

20 DETAILED DESCRIPTION OF PREFERRED EMBODIMENT(S)

Hereinafter, embodiments according to the present invention will be fully

explained with reference to the attached drawings. FIG. 1 is a plane view showing an example of an electrostatic chuck according to the present invention and FIG. 2 is a cross-sectional view thereof.

In an embodiment shown in FIG. 2, a dielectric layer 1a and an insulative support 5 base plate 1b are comprised of the same material, and integrally formed with a layer-laminated structure. FIG. 3 is a cross-sectional view showing the condition of attracting an insulative substrate 10 by an electrostatic chuck 1. By applying voltage to electrodes 7 through conductors 12 for applying voltage, an attracting force is generated between the insulative substrate 10 and the electrostatic chuck 1, thereby attracting the 10 insulative substrate 10 at protrusions 2 and an outer peripheral seal ring 3 (hereinafter, collectively referred to as a "solid-body contact portion"). Also, the electrostatic chuck 1 is connected through a connector portion 11 onto a metal plate 6, and heating/cooling is conducted to the electrostatic chuck 1 by passing a medium through a medium flow passage 8 which is provided within the metal plate 6.

15 FIGS. 4 through 6 show various examples of a pattern of the electrodes 7 which are formed on one surface of the dielectric. By using the electrodes 7 with a plurality of pairs, radio-frequency current which is used in a plasma process for SOS or SOI wafers can be dispersed into each of the electrodes, thereby enabling to reduce a load for each of electrically conductive terminals or the like.

20 Gas is supplied through a gas supply conduit 13 from a gas supply opening 5 and enclosed within a gas enclosure portion 9. In order to quickly and uniformly enclose the gas, grooves 4 are formed on the surface of the electrostatic chuck 1. Through the gas enclosure portion 9 and the solid-body contact portion, heat transmission is conducted between the insulative substrate 10 and the electrostatic chuck 1.

25 With the provision of a gas pressure gauge 16 in the vicinity of the gas supply conduit, signal voltage is outputted in the range of 0 to 10 V by pressure.

In the gas conduit, a pressure control valve 17 is provided, and opened and closed by comparing the signal voltage of the gas pressure gauge 16 with a preset value, thereby

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enabling to adjust the pressure of the gas to the preset value.

The measurement results of the electrostatically attracting force in a case of changing the properties of the dielectric are shown in Table 1.

5

TABLE 1

No.	Scope Of Present Invention	Dielectric Material	Material To Be Attracted	Thickness (μm)	Resistivity Of Dielectric (Ωcm)	Relative Dielectric Constant Of Dielectric	Surface Roughness Of Dielectric Ra (μm)	Electrostatically Attracting Force (g/cm ²)
1A	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	Low Alkaline Glass, Substrate Thickness 0.6 mm, Relative Dielectric Constant 5	500	10 ¹⁰	9	0.25	>300
1B	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	Low Alkaline Glass, Substrate Thickness 0.6 mm	500	10 ¹¹	9	0.25	>300
1C	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	Low Alkaline Glass, Substrate Thickness 0.6 mm	500	10 ¹²	9	0.25	>300
1D	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	Low Alkaline Glass, Substrate Thickness 0.6 mm	500	10 ¹³	9	0.25	>300
1E	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	Low Alkaline Glass, Substrate Thickness 0.6 mm	1000	10 ¹¹	9	0.25	>300
1F	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	Low Alkaline Glass, Substrate Thickness 0.6 mm	500	10 ¹¹	9	0.4	250
1G	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	Low Alkaline Glass, Substrate Thickness 0.6 mm	500	10 ¹¹	9	1.0	50
1H	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	Quartz Glass, Thickness 5 mm, Relative Dielectric Constant 4	500	10 ¹¹	9	0.25	>300
1I	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	Sapphire, Thickness 0.5 mm, Relative Dielectric Constant 10	500	10 ¹¹	9	0.25	>300
1J	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	High Dielectric Substrate (Relative Dielectric Constant 120, Thickness 0.5 mm)	500	10 ¹¹	9	0.25	>300
1K	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	High Dielectric Substrate (Relative Dielectric Constant 10,000, Thickness 0.5 mm)	500	10 ¹¹	9	0.25	>300
1L	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	Polyimide Film (Thickness 50 μm)	500	10 ¹¹	9	0.25	100
1M	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	SOS Wafer	500	10 ¹¹	9	0.25	>300
1N	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered Body	SOS Wafer	500	10 ¹¹	9	0.25	>300
1O	○	Al ₂ O ₃ -Cr ₂ O ₃ -TiO ₂ Ceramic Sintered	Polycrystal Alumina Substrate, Thickness	500	10 ¹¹	9	0.25	>300

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		Body	0.6 mm, Surface Roughness Ra 0.1 μ m, Relative Dielectric Constant 10					
1P	○	$\text{Al}_2\text{O}_3\text{-Cr}_2\text{O}_3\text{-TiO}_2$ Ceramic Sintered Body	Poly crystal Alumina Substrate, Thickness 0.6 mm, Surface Roughness Ra 0.4 μ m, Relative Dielectric Constant 10	500	10^{11}	9	0.25	>300
2	○	Al_2O_3 Ceramic Sintered Body	Low Alkaline Glass, Substrate Thickness 0.6 mm	500	10^{13}	9	0.1	100
3	○	BaTiO_3 Ceramic Sintered Body	Low Alkaline Glass, Substrate Thickness 0.6 mm	500	10^{11}	120	0.1	150
4	○	BaTiO_3 Ceramic Sintered Body	Low Alkaline Glass, Substrate Thickness 0.6 mm	500	10^{10}	10,000	0.2	100
5	○	BaTiO_3 Ceramic Sintered Body	Low Alkaline Glass, Substrate Thickness 0.6 mm	500	10^9	20,000	0.3	100
6	○	SIC Ceramic Sintered Body	Low Alkaline Glass, Substrate Thickness 0.6 mm	500	10^{10}	120	0.1	>300
7	○	Silicon Rubber	Low Alkaline Glass, Substrate Thickness 0.6 mm	500	10^{10}	3	0.4	150

In the measurement of the electrostatically attracting force, a material to be attracted having an area of 5 cm^2 was prepared, DC voltage in the range of 3 to 10 KV was applied to the electrostatic chuck. When the material to be attracted started moving against the electrostatically attracting force by applying force to the material to be attracted in the horizontal direction, the moving force was measured by a spring scale. Because the maximum load of the spring scale was 300g, it was impossible to measure force being larger than that. However, if the coefficient of static friction between the dielectric and the material to be attracted is 0.2, the electrostatically attracting force will correspond to reaction about five (5) times as large as the measured value. Therefore, the electrostatically attracting force will correspond to the tensile strength of 300g/cm^2 in the case where the measured value is 300g/5cm^2 . This value corresponds to about 30 kPa, which is enough to attract the material to be attracted within a vacuum chamber. In order to make the shape of the dielectric uniform, it was set to be 1 mm in the width of the electrode, 1 mm in the distance between the electrodes, and 0.5 mm in the thickness of the dielectric.

1A through 1D and 2 show the electrostatically attracting force in a case of

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varying the resistivity of the dielectric substrate. The resistivity does not have an influence to the electrostatic force very much; however, it is preferable that the resistivity be less than or equal to 10^{13} Ωcm , which creates larger electrostatically attracting force.

1F and 1G show the electrostatically attracting force in a case of varying the 5 surface roughness of the dielectric substrate. Compared to 1B, it is preferable that the surface roughness be less than or equal to $\text{Ra } 0.25 \mu\text{m}$.

The surface roughness of the material to be attracted used in the present embodiment is less than or equal to $\text{Ra } 0.1 \mu\text{m}$, except for the substrate of polycrystal alumina in 1P.

10 1B and 2 through 6 show the electrostatically attracting force in a case of varying the dielectric material. As the properties of the dielectric, the resistivity rather than the relative dielectric constant has a larger relationship to the electrostatically attracting force. With regards to the dielectric material, the most stable and large attracting force can be achieved by using ceramic sintered body obtained by adding chromium oxide and/or 15 titanium oxide to alumina, and the material obtained by adding a sinter assisting material thereto.

1B and 1H through 1N show the electrostatically attracting force in a case of varying the kind of the material to be attracted. The result shows that different insulative materials can be electrostatically attracted, and that the larger the relative dielectric 20 constant of the material to be attracted, the larger the force.

In 1O and 1P, a substrate of polycrystal alumina is used as a material to be attracted, the surface roughness thereof is varied, and then the electrostatically attracting force is measured. The result shows that the sufficient force can be obtained if the surface roughness of the material to be attracted is around $\text{Ra } 0.4 \mu\text{m}$. Therefore, when the 25 relative dielectric constant of the material to be attracted becomes large, the surface roughness of the material to be attracted can be degraded.

2 through 7 show the electrostatically attracting force in a case of varying the

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dielectric material. The result shows that the sufficient force can be obtained if a material other than ceramic sintered body obtained by adding chromium oxide and/or titanium oxide to alumina is used. In a case of glass for a PDP as a material to be attracted, it is preferable to use a material of rubber group which is hard to damage the glass is effective from the viewpoint of visibility. In the present embodiment, silicon rubber is used; however, natural rubber, chloroprene rubber, butyl rubber, nitrile rubber, fluorocarbon rubber, or resin such as polyurethane, PTFE, or the like, may be used. In this instance, it is preferable that the volume resistivity thereof be less than or equal to $10^{13} \Omega \text{ cm}$.

Table 2 shows the relationship between the electrostatically attracting force with respect to a glass substrate and the applied voltage (10 kV) in a case of using ceramic sintered body obtained by adding chromium oxide and/or titanium oxide to alumina, and varying the pattern of the electrodes in the electrostatic chuck according to the present invention.

15

TABLE 2

No.	Scope Of Present Invention	Thickness of Dielectric (μm)	Width of Electrodes (mm)	Distance Between Electrodes (mm)	Electrostatically Attracting Force ($\text{g}/5\text{cm}^2$) 10kV
7	X	300	0.3	0.3	Break down
8	O	300	0.5	0.5	Break down
9	O	300	0.7	0.7	>300
10	O	300	1.0	1.0	>300
11	O	300	2.0	2.0	180
12	X	300	3.0	3.0	30
13	O	300	0.5	1.0	>300
14	O	300	0.5	1.5	200
15	O	300	2.0	1.0	250
16	O	300	4.0	1.0	120
17	X	300	6.0	1.0	30
18	X	400	0.3	0.3	Break down
19	O	400	0.5	0.5	>300
20	O	400	0.7	0.7	>300
21	O	400	1.0	1.0	>300
22	O	400	2.0	2.0	120
23	X	400	3.0	3.0	30
24	O	400	0.5	1.0	>300
25	O	400	0.5	1.5	200
26	O	400	2.0	1.0	200

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27	○	400	4.0	1.0	100
28	×	400	6.0	1.0	20
29	×	500	0.3	0.3	Break down
30	○	500	0.5	0.5	Break down
31	○	500	0.7	0.7	>300
32	○	500	1.0	1.0	280
33	○	500	2.0	2.0	100
34	×	500	3.0	3.0	20
35	○	500	0.5	1.0	>300
36	○	500	0.5	1.5	200
37	○	500	2.0	1.0	165
38	○	500	4.0	1.0	45
39	×	500	6.0	1.0	25
40	×	700	0.3	0.3	Break down
41	○	700	0.5	0.5	240
42	○	700	0.7	0.7	240
43	○	700	1.0	1.0	220
44	○	700	2.0	2.0	90
45	×	700	3.0	3.0	20
46	○	700	0.5	1.0	260
47	○	700	0.5	1.5	150
48	○	700	2.0	1.0	140
49	○	700	4.0	1.0	50
50	×	700	6.0	1.0	20
51	×	1,000	0.3	0.3	Break down
52	○	1,000	0.5	0.5	200
53	○	1,000	0.7	0.7	200
54	○	1,000	1.0	1.0	180
55	○	1,000	2.0	2.0	70
56	×	1,000	3.0	3.0	20
57	○	1,000	0.5	1.0	220
58	○	1,000	0.5	1.5	120
59	○	1,000	2.0	1.0	120
60	○	1,000	4.0	1.0	30
61	×	1,000	6.0	1.0	10
62	×	2,000	0.3	0.3	Break down
63	○	2,000	0.5	0.5	170
64	○	2,000	0.7	0.7	130
65	○	2,000	1.0	1.0	100
66	○	2,000	2.0	2.0	10
67	×	2,000	3.0	3.0	10
68	○	2,000	0.5	1.0	120
69	○	2,000	0.5	1.5	30
70	○	2,000	2.0	1.0	70
71	○	2,000	4.0	1.0	30
72	×	2,000	6.0	1.0	10

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In a case of the pattern having the same width of the electrode and the same distance between the electrodes, the maximum electrostatically attracting force can be obtained when the thickness of the dielectric is 0.3 mm, and there is a tendency that the thinner the thickness thereof, the larger the electrostatically attracting force.

5 If both of the width and the distance are equal to or greater than 0.5 mm, the electrostatically attracting is available. However sufficient insulation between the electrodes cannot be achieved if the distance between the electrodes is smaller than 0.5 mm. As a result of this, there are cases where the electrostatically attracting cannot be obtained.

10 In a case of comparing the dielectric having the same thickness, the smaller the width of the electrode, the larger the electrostatically attracting force.

15 In a case where the distance between the electrodes is larger than 2 mm, the electrostatically attracting force can hardly be obtained. In the present embodiment, the voltage applied is raised to 10 kV. It is expected that the sufficient force can be obtained even if the distance between the electrodes is 2 mm, by applying voltage being larger than that.

In a case of comparing the dielectric having the same thickness and the same width of the electrode, there is a tendency that the electrostatically attracting force becomes small when the distance between the electrodes is larger than the thickness of the dielectric.

20 The foregoing show that a large electrostatically attracting force can be obtained in a case where the thickness of the dielectric is thin, the width of the electrode is small, and the distance between the electrodes is almost equal to the width of the electrode.

25 In a case of electrostatically attracting a glass substrate as a material to be attracted, it can be put to practical use by setting the thickness of the dielectric in the range of 0.3 to 2.0 mm, the distance between the electrodes in the range of 0.5 to 1.0 mm, the width of the electrode in the range of 0.5 to 4.0 mm, and the resistivity of the dielectric to be less than or equal to $10^{13} \Omega\text{cm}$. It is more preferable that the thickness of the dielectric be in the range of 0.3 to 1.0 mm, the distance between the electrodes in the range of 0.5 to 1.0 mm,

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the width of the electrode in the range of 0.5 to 1.0 mm, and the resistivity of the dielectric to be less than or equal to 10^{13} Ω cm.

Hereinafter, an embodiment of a substrate heating/cooling apparatus will be described.

FIGS. 7 through 9 are graphs showing data on thermal attraction experiments and cooling experiments on an insulative substrate. A glass substrate (i.e., a low alkaline glass) is used as the insulative substrate 10.

FIG. 7 is a graph showing the relationship between the temperature of an insulative substrate and the pressure of the gas for heating/cooling to be supplied into a space between the insulative substrate and the attracting surface of the dielectric, in which the insulative substrate is positioned in a substrate heating/cooling apparatus which is provided within a vacuum chamber. The thermal characteristic in a case where a heat flow of 2W/cm^2 is supplied from the upper surface of the insulative substrate 10 is shown by expressing the pressure of the above-mentioned gas on x-axis and the surface temperature of the insulative substrate 10 on y-axis. This graph shows that the temperature of the insulative substrate 10 can be controlled by varying the gas pressure enclosed in a gas enclosure portion 9. He gas is mainly used in the present experiment; however, the same heating/cooling effect can be obtained by using Ar or N_2 .

In order to increase efficiency of the heating/cooling by supplying higher pressure, it is necessary to make the height of the protrusions 2 on the attracting surface of the dielectric 19 low and thereby bring the pressure of the gas into the region of a molecular flow. For example, in order to bring the above-mentioned gas in the range of 0 to 13329 Pa (0 to 100 Torr) into the region of a molecular flow, the height of the protrusions 2 may be set to be less than or equal to 5 μm . In this instance, in order to quickly and uniformly enclose the above-mentioned gas, the formation of the grooves 4 is important as well as the protrusions 2.

In a case where only the protrusions are formed on the surface of the electrostatic chuck, it takes time until the pressure within the space comes to be uniform depending

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upon the height of the protrusions. Therefore, by forming of the grooves from the gas supply opening, the time is reduced until the pressure within the space comes to be uniform. With regards to the shape and the pattern of the grooves, the effect can be achieved when they are formed in a radial pattern from the gas supply opening, and they are equal to or greater than 1.0 mm in the width and equal to or greater than 50 μm in the depth. Preferably, the width is equal to or greater than 1.5 mm and the depth is equal to or greater than 250 μm , and thereby the time until the pressure distribution in the shape comes to be uniform is less than or equal to 5 seconds. The effect can be further increased if the grooves are formed in a concentric pattern as well as a radial pattern.

10 As shown in FIG. 8, by varying the applied voltage, it is possible to vary the temperature of the insulative substrate 10. In this instance, by varying the surface roughness of the electrostatic chuck, it is possible to adjust the temperature of the insulative substrate 10.

15 Further, as shown in FIG. 9, the experiment result shows that the temperature of the insulative substrate 10 is varied by varying the ratio of a contact area. In order to vary the contact area ratio, it is necessary to vary the number and the diameter of the protrusions. The diameter of the protrusions in the present embodiment is 5 mm, and the width of the seal ring is 4 mm. The number of the protrusions is converted from the contact area ratio. The protrusions are distributed upon the surface of the electrostatic chuck in the 20 substantially equal position with regards to each other.

25 The present embodiment shows that large heating/cooling effect on the insulative substrate 10 can be obtained by enclosing the high gas pressure of 6664 Pa (50 Torr) in the gas enclosure portion 9. However, in order to enclose such high gas pressure, it is necessary that the electrostatic chuck generate a large attracting force. For example, in order to enclose the gas pressure of 1333 Pa (10 Torr) in a case where the contact area ratio is 20 %, theoretically, the attracting force of at least 13 g/cm² is required. Therefore, the electrostatic chuck having a very large attracting force is required. As a material for an insulating layer of the electrostatic chuck is used ceramic sintered body comprised of mainly alumina, and chromium oxide (Cr₂O₃), titanium oxide (TiO₂), and a sinter assisting 30 material added thereto in an appropriate amount. The attracting force in this material is

about 300 g/cm² under application of 10 KV, which is the same as 1A - 1C mentioned above, and the tensile strength in the vertical direction can be assumed to be 300 g/cm². Even if the contact area ratio is 20%, it can be ensured that the attracting force is equal to or greater than 60 g/cm². Therefore, it is possible to sufficiently attract the insulative substrate.

A low alkaline glass is used as the insulative substrate 10 in the present embodiment; however, the electrostatic chuck according to the present invention can in general also be applied to other electrical insulative substrates and/or films.

With the provision of a heater within the insulative support base plate of the heating/cooling apparatus for an insulative substrate, and an optical thermometer, a thermocouple, or another noncontact thermometer as a means for measuring the temperature on the material to be attracted, the signal outputted from the measurement apparatus is compared with a predetermined value, and thereby the temperature of the material to be attracted can easily be controlled. In a case where the temperature of the insulative substrate cannot directly be measured, it is possible to maintain the temperature of the insulative substrate based on a data base in which the gas pressure, the applied voltage, the ratio of the solid-body contact area, the supplied thermal energy, the flow rate of the medium, the temperature of the medium, or the like are compiled in advance and linked together.

20 With the provision of the heating/cooling apparatus for an insulative substrate according to the present embodiment within a reaction chamber, it is possible to easily control the temperature in a semiconductor manufacturing process, in particular, in a plasma CVD for an SOS or SOI, a plasma etching, a sputtering, or the like.

As is fully explained in the above, according to the present invention, since a material to be processed can be attracted with the electrostatic chuck even if it is an insulative material, it is possible to easily heat/cool the insulative substrate with the heating/cooling apparatus in which the electrostatic chuck is installed, and thereby it is possible to control the temperature of the insulative substrate at a predetermined value.

What is claimed is: **<Claims including amendment under Article 34>**

1. (amended) An electrostatic chuck for attracting an insulative substrate, used under a vacuum atmosphere, comprising:
 - 5 a dielectric layer having a first surface which is made an attracting surface for attracting an insulative substrate, and a second surface on which are provided a plurality of electrodes;
 - an insulative support base plate for fixing said dielectric layer thereon;
 - 10 a plurality of electrically conductive terminals which are provided on said insulative support base plate; and
 - 15 a means for electrically connecting said electrodes which are provided on said dielectric layer and said electrically conductive terminals.
2. An electrostatic chuck according to claim 1, wherein the resistivity of said dielectric layer is less than or equal to 10^{13} Ω cm at room temperature.
3. An electrostatic chuck according to claim 1 or 2, wherein the thickness of said dielectric layer is less than or equal to 2 mm.
4. An electrostatic chuck according to any one of claims 1 - 3, wherein said dielectric layer is comprised of ceramic obtained by adding chromium oxide and/or titanium oxide to alumina as a main raw material and firing.
5. An electrostatic chuck according to any one of claims 1 - 4, wherein the attracting surface of said dielectric layer has grooves, protrusions and an outer peripheral seal ring.
- 20 6. An electrostatic chuck according to any one of claims 1 - 5, wherein said plurality of electrodes which are provided on the second surface of said dielectric layer form a pair, the width of each electrode is less than or equal to 4 mm, the distance between the electrodes is less than or equal to 2 mm, and each electrode is intricate in a comb-tooth shape.

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7. An electrostatic chuck according to any one of claims 1 - 5, wherein said plurality of electrodes which are provided on the second surface of said dielectric layer form a plurality of pairs, the width of each electrode is less than or equal to 4 mm, the distance between the electrodes is respectively less than or equal to 2 mm, and each electrode is intricate in a comb-tooth shape.

8. An electrostatic chuck according to any one of claims 1 - 7, wherein said insulative support base plate is comprised of a material having a larger resistivity than that of said dielectric layer.

9. An electrostatic chuck according to any one of claims 1 - 8, wherein said 10 electrically conductive terminals are formed through any one of hard solder, soft solder, and a conductive adhesive.

10. An electrostatic chuck according to any one of claims 1 - 9, wherein said means for electrically connecting is any one of a conductive wire, a conductive rod, and filling of conductive resin or solder.

11. (amended) A method for electrostatically attracting and processing an 15 insulative substrate, comprising the steps of:
providing a dielectric layer having a first surface which is made an attracting surface for attracting an insulative substrate, and a second surface on which are provided a plurality of electrodes;

providing an insulative support base plate for fixing said dielectric layer thereon;

providing a plurality of electrically conductive terminals which are provided on said insulative support base plate;

providing a means for electrically connecting said electrodes which are provided on said dielectric layer and said electrically conductive terminals respectively;

25 providing a high voltage source;

providing a means for electrically connecting said high voltage source and said electrically conductive terminals; and thereby

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electrostatically attracting the insulative substrate positioned on said attracting surface under a vacuum atmosphere.

12. (canceled)

13. (amended) A method for electrostatically attracting and processing an insulative substrate according to claim 11, wherein the insulative substrate is electrostatically attracted and gas for heating/cooling of the substrate is enclosed within a space defined between the substrate and the attracting surface of the dielectric layer.

14. An apparatus for heating/cooling and processing an insulative substrate, comprising:

10 an electrostatic chuck according to any one of claims 1 - 10;

a plate for supporting said electrostatic chuck, in which is formed a flow passage for a medium; and

a means for bonding said electrostatic chuck and said plate.

15. An apparatus for heating/cooling and processing an insulative substrate, comprising:

an electrostatic chuck according to any one of claims 1 - 10;

a plate for supporting said electrostatic chuck, in which is formed a flow passage for a medium;

a means for bonding said electrostatic chuck and said plate; and

20 a gas supply conduit penetrating the dielectric layer, the insulative support base plate and the plate;

a pressure gauge for measuring the gas pressure;

25 a pressure control valve having a function of opening/closing a valve so as to control the pressure at a predetermined value by inputting an electric signal outputted by the pressure gauge; and

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an apparatus for measuring the temperature of the insulative substrate or a data base in which the relationship between the temperature of the insulative substrate and the gas pressure is recorded,

5 wherein the temperature of the insulative substrate can be adjusted to the predetermined value under a vacuum atmosphere.

16. (amended) An electrostatic chuck according to any one of claims 1 - 10, wherein the insulative substrate is comprised of glass.

17. (added) An apparatus for heating/cooling and processing an insulative substrate according to claim 14 or 15, wherein the insulative substrate is comprised of 10 glass.

-18. (added) A method for electrostatically attracting and processing an insulative substrate according to claim 11, wherein the electrostatically attracting force is equal to or greater than 30g/cm².

19. (added) A method for electrostatically attracting and processing an insulative substrate according to claim 11, wherein the electrostatically attracting force is equal to or greater than 300g/cm².

20. (added) An apparatus for electrostatically attracting an insulative substrate, comprising:

a dielectric layer having a first surface which is made an attracting surface for attracting an insulative substrate, and a second surface on which are provided a plurality of electrodes;

an insulative support base plate for fixing said dielectric layer thereon;

a plurality of electrically conductive terminals which are provided on said insulative support base plate;

25 a means for electrically connecting said electrodes which are provided on said dielectric layer and said electrically conductive terminals respectively;

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a high voltage source; and

a means for electrically connecting said high voltage source and said electrically conductive terminals,

wherein the insulative substrate positioned on said attracting surface is
5 electrostatically attracted under a vacuum atmosphere.

21. (added) An apparatus for electrostatically attracting an insulative substrate according to claim 20, wherein the insulative substrate is electrostatically attracted and gas for heating/cooling of the substrate is enclosed within a space defined between the substrate and the attracting surface of the dielectric layer.

10 22. (added) An apparatus for electrostatically attracting an insulative substrate according to claim 20, wherein the electrostatically attracting force is equal to or greater than 30g/cm^2 .

15 23. (added) An apparatus for electrostatically attracting an insulative substrate according to claim 20, wherein the electrostatically attracting force is equal to or greater than 300g/cm^2 .

24. (added) A method for electrostatically attracting and processing according to any one of claims 11, 13, 18 and 19, wherein the insulative substrate is comprised of glass.

25. (added) An apparatus for electrostatically attracting an insulative substrate according to any one of claims 20 - 23, wherein the insulative substrate is comprised of
20 glass.

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ABSTRACT OF DISCLOSURE

According to the present invention, there is provided an electrostatic chuck for electrostatically attracting an insulative substrate, an apparatus for heating/cooling an insulative substrate using the electrostatic chuck, and a method for controlling the 5 temperature of an insulative substrate. The shape and the properties of the dielectric, and the shape of the electrodes, which form the electrostatic chuck, are disclosed. Also the apparatus for heating/cooling an insulative substrate comprising a plate, a gas supply conduit and a temperature controlling system, and the apparatus for processing an insulative substrate in which the apparatus for heating/cooling an insulative substrate is 10 installed are disclosed.